NERRS Science Collaborative Progress Report for the Period 03/01/12 through 08/31/12

Project Title: Carbon Management in Coastal Wetlands: Quantifying Carbon Storage and Greenhouse Gas Emissions by Tidal Wetlands to Support Development of a Greenhouse Gas Protocol and Economic Assessment

Principal Investigator(s): Alison Leschen, Project Coordinator, Manager of the Waquoit Bay National Estuarine Research Reserve (WBNERR)

Project start date: November 15, 2012

Report compiled by: Kate Harvey, Collaboration Assistant and Tonna-Marie Rogers, Collaboration Lead

Contributing team members and their role in the project:

- Kevin Kroeger (for Applied Science Investigators)
- Serena Moseman-Valtierra (for Applied Science Investigators)
- Jim Tang (for Applied Science Investigators)
- Omar Abdul-Aziz (Modeler)
- Steve Emmett-Mattox, Restore America's Estuaries (Intended User Representative)
- Thomas Walker (Manomet Center for Conservation Sciences (Intended User Representative)
- Alison Leschen (Principal Investigator, Manager, WBNERR)
- Tonna-Marie Rogers (Collaboration Lead, CTP Coordinator, WBNERR)
- Kate Harvey (Collaboration Assistant, WBNERR)
- Jordan Mora (Research Assistant, WBNERR)
- James Rassman (Stewardship Coordinator, WBNERR)
- Meg Gardner (NERRS Science Collaborative Intern assigned to WBNERR)

A. Progress Overview

This project is designed to address the interaction of two of the most critical management issues currently facing coastal communities, climate change and eutrophication caused by excess nitrogen loading. The project will generate information and tools that coastal decision makers can use to manage nitrogen pollution, design effective wetlands protection and restoration projects, and create policy frameworks and economic incentives to reduce greenhouse gas (GHG).

The second reporting period of project implementation included an intensive effort to prepare for and conduct initial scientific measurements at selected sites. This effort kicked off with innovative design and construction of a temporary boardwalk by WBNERR research staff to provide reliable scientific access while minimizing adverse impacts to the marsh ecosystem. Then, in July and August 2012, project team members used the boardwalk to conduct initial greenhouse gas and associated measurements. Additionally, during this reporting period, project team member Restore America's Estuaries made strides in the development of the GHG offset methodology. Further detail on project goals and reporting period tasks are below:

Project Goals	Reporting Period Tasks and Accomplishments

A. Quantify carbon sinks and GHG fluxes in tidal wetlands, and assess the impact of anthropogenic nitrogen loading, sea level rise, and climate on both carbon sequestration and net GHG emissions in tidal wetlands.	• Salt marsh infrastructure preparations • Set-up of four study sites with different nitrogen loading levels. • Development of CO2, CH4/N20 measurement system and collar installation for GHG chambers. • Field measurement of CO2, CH4, and N2O and NECB • Measurement of lateral fluxes of C and N • Sediment, water, and plant measurements
B. Develop a carbon sequestration and GHG emissions model for tidal wetlands using the collaboration between end-users and scientists to identify the specific data needs for it, and apply the model to aid the development of a tidal wetlands GHG offset protocol.	• Initiated testing of model using data from other projects.
C. Connect the conservation community with guidance on management of carbon and nitrogen and with carbon markets by providing a GHG offset protocol (methodology) that will be adopted by climate registries.	• Developed a draft of the methodology for internal review.
D. Provide to intended users (resource managers, project developers, policymakers, land use planners, and those involved with carbon markets) data and a GHG offset model that can inform planning for tidal wetlands preservation and restoration.	• No tasks scheduled for this period based on project timeline.
E. Conduct an economic assessment of the carbon sequestration and GHG benefits of tidal wetlands, including the impact of nitrogen loading, to assess the financial relevance to land conservation decisions.	• No tasks scheduled for this period based on project timeline.
F. Advance the ability of the NERRS, building on its System-Wide Monitoring Program, Biomonitoring and Sentinel Site efforts, to monitor the effects of climate change on coastal ecosystems.	• No tasks scheduled for this period based on project timeline.

B. Working with Intended Users:

Collaboration Workshop/Stakeholder Meeting

Our first formal interaction with users and stakeholders took place in the form of a collaborative learning workshop/stakeholder engagement meeting that occurred on May 3-4, 2012 at WBNERR. This workshop was one of several being delivered by Dr. Chris Feurt, CTP Coordinator at the Wells Reserve, at selected NERRS and supported by the NERRS Science Collaborative. For the purposes of this project the standard collaboration workshop that Dr. Feurt offers was adjusted to allow for incorporating stakeholder feedback on the research initiative. This made the workshop truly unique in both its purpose and delivery. Dr. Feurt led most of the workshop with assistance from designated small group facilitators.

The workshop was organized by Dolores Leonard of the NERRS Science Collaborative, Dr. Chris Feurt Tonna-Marie Rogers, WBNERR CTP Coordinator and Project Collaboration Lead. In preparation for the event the Collaboration Lead worked with project team members to identify and invite a diverse set of participants representing federal, state, local, academic and business entities as well as to prioritize a set of key questions/issues around which to gather input from stakeholders. The Collaboration Lead also coordinated presentations from selected stakeholder representatives and assisted team members delivering presentations to conduct targeted interviews intended user representatives in order to hone their presentations and gain insight into interests and concerns of these intended users. Lastly, the Collaboration Lead also conducted a series of interviews with team members as well as intended user representatives. Information gathered from these interviews provided some of the background for discussion at the workshop. Dr. Feurt also used notes from two of these interviews to demonstrate coding techniques to the Collaboration Lead and Assistant.

Over twenty intended users[1] and ten team members participated in the two-day workshop, which provided an opportunity for shared discussion of the project and educational training on collaborative processes. The workshop agenda included presentations, participatory exercises, and facilitated group discussions with intended users about how best to engage with them over the life of the project. WBNERR conducted a post workshop evaluation, which included the following highlights:

- One hundred percent (100 %) of participants who completed the survey (i.e. 21 of 21 total responses) *strongly agreed* or *agreed* that "participating in this workshop was a good use of my time." Ninety five percent (95%) of participants who completed the evaluation indicated that the workshop helped to increase their knowledge of collaboration learning and carbon management in coastal wetlands issues.
- Responses to the question "what aspects of the workshop did you find most helpful?" included:
    - Scientists and stakeholders get together to discuss the project.

[1] Intended users included representatives from Massachusetts state agencies (Department of Ecological Restoration, Department of Environmental Protection, Coastal Zone Management), local towns (Sewer Departments, Coastal Ponds Board), federal agencies (National Oceanographic and Atmospheric Administration and Environmental Protection Agency), research institutions (Boston University, Marine Biological Laboratory, Woods Hole Oceanographic Institution), and non-governmental organizations (Association to Preserve Cape Cod, The Nature Conservancy and the Falmouth 300 Committee).

- It helped me and my colleagues make concrete linkages with real end users and stakeholders. I now know who these people are!
- Learning how a collaborative effort can be applied to an existing problem.
- Meeting the whole project team and the other participants, and being involved in this collaborative process. I have been living on Cape Cod for 5 years and doing research on the nitrogen cycle for 8 but haven't been connected to the implications and potential implications of our research.
- The research project appears to be a highly innovative one in that it includes developing a group on end-users (us) from the outset of the project. Also the approach to modeling and research program are exciting and better than many projects in defining simple, useful products.
- Well-organized one of the top ten of my many meetings attended in 37 plus years.

Input gathered from intended users at this workshop was collated and incorporated into strategic planning on engagement opportunities over the course of the project (see *Integrating What We Learned* below).

Collaboration Planning

To assist with the collaboration component of the project, WBNERR hired an assistant to work with the Collaboration Lead/Reserve Coastal Training Coordinator. Kate Harvey was hired and began work in May 2012. Her tasks during this reporting period included synthesizing input from the collaboration workshop in coordination with the Collaboration Lead and developing a draft stakeholder engagement plan. The plan includes face-to-face, electronic, and two-way communication strategies.

In addition, WBNERR welcomed Meg Gardner, graduate student at the University of New Hampshire and TIDES intern, who will assist the Collaboration Lead with developing communication and outreach products, including videos, fact sheets, and website content. To date Meg has been working on creating a video series about the project and drafting fact sheets.

Methodology Intended Users Engagement

RAE has included estuary restoration expert Doug Myers as part of the project team. Dr. Myers has extensive experience in the science and practice of restoration, and until recently was a staff member of RAE member People for Puget Sound. He is familiar with the needs and opportunities of restoration programs throughout the U.S.

Integrating What We Learned

Engagement with intended users during the past six months has raised the following issues and considerations:

- *At the local level, nitrogen is king (currently):* Through the collaboration workshop and other engagement, intended users at the local level expressed a strong interest in nitrogen management on Cape Cod. They are interested in science that helps to advance the conversation on how best to manage excess nitrogen that is presently degrading coastal waters in Massachusetts. This finding was not a surprise to the team as the impact of excess nitrogen loading has been identified by WBNERR as a key priority for local decision-makers

and community members. Local intended users are interested in the carbon storage capacity of marshes but this issue is currently not at the top of their minds. The project team discussed intended users' interest in additional data on the nitrogen carrying capacity of wetlands, however, it was agreed that this level of research is beyond the scope of the funded research project. As this project progresses, the team will need to frame the carbon sequestration issue for intended users at the local level in ways that are salient and relevant to their work and existing interests. The team will also have to ascertain where and how to connect what is learned about the nitrogen component of this research to how local communities are attempting to address nitrogen pollution. The team will also share this research need with other scientists in the field to see what additional work is being done on nitrogen and carbon management in wetlands.

- *Wetlands Carbon Education*: The team received feedback that "blue carbon" is still a relatively new concept for many professionals and that education on carbon sequestration and wetlands was needed for a range of audiences including the general public, town staff and boards, agencies, and non-governmental organizations. As a result, the team will be developing multiple education and outreach tools, including video, factsheets, websites, presentations, etc. that can be used by project team members and shared with intended users and the public. The integration of these materials will be part of an overall engagement strategy with intended-users. Additionally, Alison Leschen presented a talk on the project in one of several sessions on Blue Carbon at the INTECOL conference in Orlando. Her talk and others in the sessions generated a lot of interest among scientists who had been unfamiliar with the term and concept of "Blue Carbon."
- *Pilot Testing:* After engaging with intended-users, the team identified a need to pilot test potential tools and analyses with different types of intended-users to ensure that they are answering the "right" questions for intended users. While pilot testing was intended to be part of the project, early engagement with intended users raised questions about when the appropriate time would be to conduct pilot tests. The team will further discuss this issue.

Working with Intended Users in the Next Six Months

The project team will continue to conduct educational outreach with intended users over the next six months on topics including blue carbon, wetlands functions, and potential project applications. The team will also evaluate early data and consider appropriate formats for sharing these data with intended users for the purpose of a) information sharing b) questions c) potential adjustments to measurements.

C. Progress on Project Objectives for this Reporting Period

Science Investigation and Field Research

- *Salt marsh infrastructure preparations*

The WBNERR team designed and constructed a temporary boardwalk which provides reliable research access while minimizing adverse impacts to the marsh ecosystem. Less than 10% of the structure actually rests on the salt marsh surface. The WBNERR boardwalk is a unique design, which provides an innovative solution to a common salt marsh research challenge.

- *Development of CO_2, CH_4/N_20 measurement system and collar installation for GHG chambers.*
- *Field measurement of CO_2, CH_4, and N_2O and NECB*
- *Measurement of lateral fluxes of C and N*
- *Sediment, water, and plant measurements*

Vertical flux

The team developed a large, novel chamber system (2 ft X 2 ft X2 ft) for vertical gas flux measurement in salt marsh. This chamber was connected to the state-of-the-art gas measurement system for in-situ measurement of N_2O, CO_2, and CH_4fluxes (Los Gatos Research and Picarro). The air inside the chamber was drawn and circulated within the analyzers, and concentration increase was recorded. The team calculated the flux based on the increase of gas concentration over time when the chamber was closed. Vertical gas fluxes were measured at Sage Lot Pond, the reference salt marsh site, beginning in June 2012. Contrasts were drawn between fluxes in high marsh zones (*Distichlisspicata*-dominated) and low marsh zones (*Spartina alterniflora*-dominated) on two dates (June and July 2012). In the low marsh at Sage Lot Pond, a total of 9 plots were established, and in the high marsh, six plots were selected for these studies. These were selected to enable the team to quantify as much spatial variation as possible from the boardwalk while minimizing disturbance to the marsh. Measurements were also concentrated in low marsh zones around a tidal cycle (from dawn to dusk).

In addition to the Sage Lot site, the team selected three other sites along a N gradient after visiting nearby salt marshes three times since February 2012. These sites were selected using a list of criteria developed by the team such as plant species and diversity, water channel depth and width, salinity, accessibility, etc. With the help of WBNERR staff, the team acquired landowner permission to measure at all salt marsh sites along the N gradient in August 2012. The field sites now include Sage Lot Pond (no N loading where measurement has been started), Hamblin Pond (low N loading), Great Pond (intermediate N loading), and Eel Pond (high N loading). The team will start to take measurements at all four sites by the end of August.

In tandem with vertical gas flux measurements (for N_2O, CH_4, and CO_2), plant properties (density, average height, plant species composition) and soil properties (pH, surface moisture, temperature, and salinity) were also measured.

Lateral fluxes

Full seasonal and annual budgets of tidal material exchange at four salt marshes require a large effort, and the team working on the effort has grown as work has progressed (Table 1).

Table 1. Direct participants in lateral fluxes effort

Name	Role	Institution
Kevin Kroeger	Principle Investigator	USGS Woods Hole
Neil Ganju	Co-Principle Investigator	USGS Woods Hole
John Pohlman	Co-Principle Investigator	USGS Woods Hole
Adrian Green	Research Technician	USGS Woods Hole
Sandra Baldwin	Research Technician	USGS Woods Hole
Wally Brooks	Research Technician	USGS Woods Hole

Michael Casso	Research Technician	USGS Woods Hole
Charles Worley	Research Technician	USGS Woods Hole
Aleck Wang	Collaborator—inorganic carbon system analyst	Woods Hole Oceanographic Institution
Amanda Spivak	Collaborator—organic carbon system analyst	Woods Hole Oceanographic Institution

In April 2012 the team began gathering lateral flux data at the Sage Lot Pond site on water and chemical exchanges between the marsh and adjoining estuary. Multiple field efforts have included deployments of sensors for collection of continuous data, in addition to collections of discrete samples for measurements chemistry and concentrations of major forms of carbon and greenhouse gases. On April 9 and on July 20 the team conducted full tidal cycle (14 hour) campaigns of flow and chemical sampling to calculate net exchanges between marsh and estuary.

Table 2. Parameters to be measured continuously at each site using sensor deployments

Parameter	Proxy for:	Manufacturer
Integrated water velocity	Water flux	Sontek
Colored Dissolved Organic Matter (CDOM)	Dissolved organic carbon	YSI or WetLabs
Suspended particles	Particulate organic carbon; sediment	YSI or WetLabs
pH	Carbon dioxide (under investigation)	YSI
Chlorophyll a	Phytoplankton biomass	YSI or WetLabs
Dissolved oxygen		YSI
Salinity		YSI
Temperature		YSI
Oxidation/reduction potential		YSI
Pressure	Water depth	YSI

Due to temporal variability, early on in the field work it became clear that near-continuous data on several parameters will be required to assemble adequate budgets of carbon and GHG. A further critical result noted in our first full tidal cycle effort was that the preponderance of water exchange, and thus of chemical flux into and out of the marsh, occurs during the roughly two hours prior and two hours after high tide (Fig. 1). This presents a challenge because near high tide the differences are very small in constituent (organic carbon, inorganic carbon, GHG) concentrations between outflowing and inflowing water. A partial solution to this problem is to use sensors to make many very frequent measurements of flow and concentration to increase confidence in any measured difference.

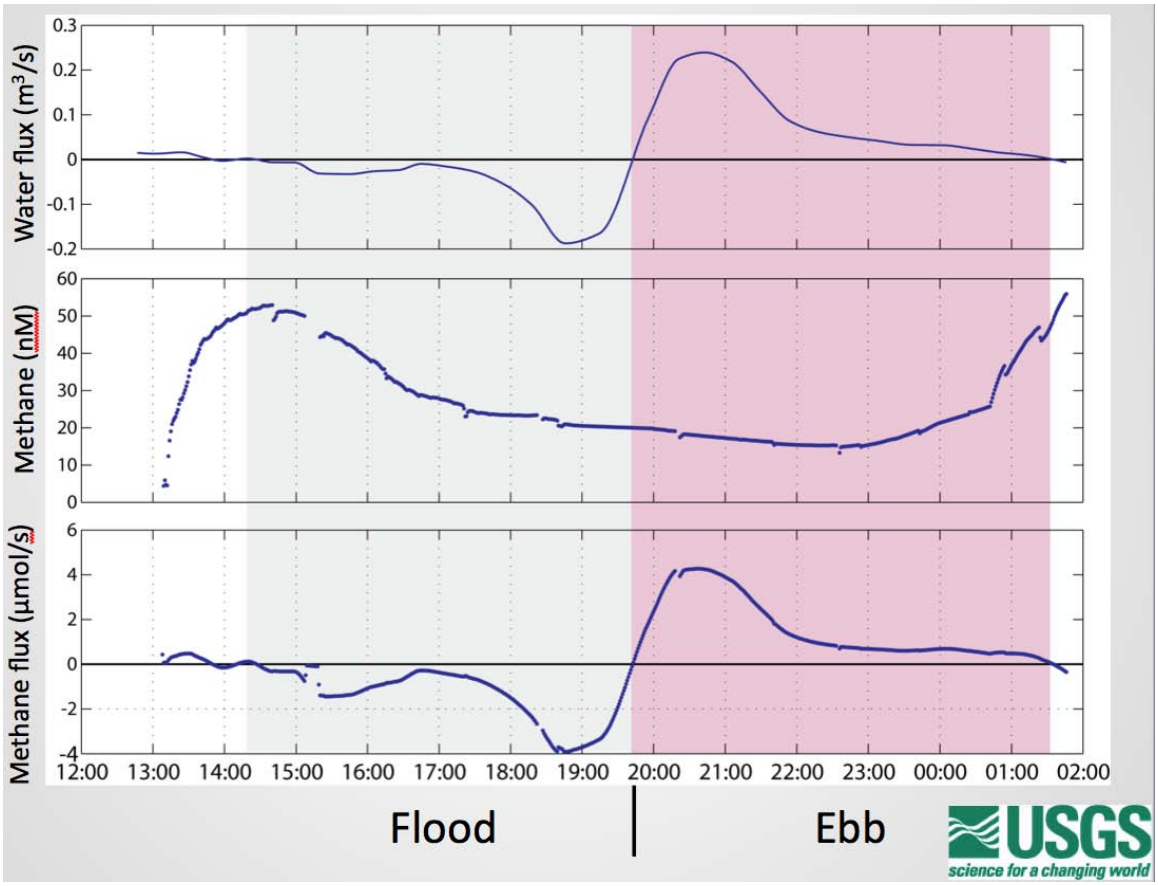

Figure 1. Measurements of water flux (top panel), near-continuous measurements of methane, CH_4 concentration (middle panel), and calculated lateral flux rates of dissolved methane into (flood) and out of (ebb) the marsh at Sage Lot Pond, April 9, 2012. Methane concentrations were measured by coupling a Picarro gas analyzer to an air/water equilibrator.

Within the USGS Woods Hole Science Center a limited number of sensors were available on a limited schedule. Access to these sensors has allowed us to begin making the needed measurements. However, in response to the new information gathered, for lateral fluxes the team now plans to purchase, install and maintain sensors at the four study sites comprising the nitrogen loading gradient to collect the data that will be the backbone of our budget calculations. The sensors are being purchased with USGS funds, and will cover several of the needed parameters. However, there are some critical parameters, particularly nitrous oxide and methane, that cannot be measured continuously using sensors. Thus, the sensor data will be supplemented with a schedule of 1) full tidal cycle (14 hour) measurements of all chemical parameters including measurements of dissolved GHG using the Picarro and Los Gatos gas analyzers (approximately three per year per site), and 2) weekly to biweekly sample collections of ~three to four hours each at particular portions of the tidal cycle. In addition to the sensors mentioned, USGS has purchased a Picarro carbon dioxide and methane stable isotope analyzer that will be available at no cost to this Science Collaborative project.

GHG Methodology

RAE has convened and contracted with an expert team to draft the first tidal wetlands restoration greenhouse gas offset methodology, including noted wetland scientists Dr. Pat Megonigal, Smithsonian Environmental Research Center, Dr. Brian Needelman, University of Maryland, and Dr. Steve Crooks, an independent wetlands carbon consultant; estuary restoration specialist Dr. Doug Myers from the Puget Sound region; and carbon offsets expert Igino Emmer of Silvestrum.

The team met in June for 2.5 days to discuss strategies and develop approaches to the methodology. The scope of the methodology will be tidal wetlands restoration and may be expanded to include seagrass restoration and tidal wetlands creation through beneficial use of dredge material. A decision about scope will be made in the next two months.

An initial draft has been prepared and is being circulated among those team members working on the methodology.

Biogeochemical Model

A theoretical version of the proposed user-friendly GHG emissions and C-sequestration model was previously developed and is undergoing revisions. The team will test the model in the next six months with WBNERR data collected during summer 2012. During the past months, the team has been analyzing large scale GHG emissions data from several sites within the Florida Everglades Ecosystem to obtain insights into the relevant biogeochemical processes. The analysis is underway and expected to complement the GHG emissions modeling for the tidal wetland ecosystems.

Economic and Policy Analysis

Tom Walker participated in the collaborative workshop/stakeholder meeting with the goal to better understand the interests of intended-users. Feedback gathered from this workshop/meeting will help to inform design of economic and policy analyses which are scheduled for year three of the project.

Team Coordination

The project team continues to use Basecamp as a communication and project management tool. Throughout the reporting period, the team has held monthly conference calls to share project updates, discuss intended user feedback, and provide input on project tools and resources (e.g. website).

Communication Tools and Strategies

Website: The Collaboration Assistant created a project website using Wordpress (www.wbnerrwetlandscarbon.net) which will incorporate project updates, team information, and general findings. The website is intended to be a resource for the general public and intended users seeking basic information on the project. The website will be linked to WBNERR, project team members' websites and that for the NERRS Science Collaborative

Videos: Meg Gardner- project intern- has begun developing a video series on the project, which will include a project overview, discussion of key science topics, and potential applications. Her videos will integrate science team and intended-users perspectives and be used as educational tools. The

videos will be posted on the project website and available for use by project team members. Meg has already created a video on the boardwalk which was put together to support field operations.

Written Collateral: The project team is using content developed for NERRS Science Collaborative Reports for newsletter updates, website content, and presentations for intended users and the general public.

Next Six Months

- *Science and Field Investigations*: During the next six months the team expects to fully implement the sensor deployments and discrete sample collections schedule described here. The team will further continue to analyze new data as they become available, to arrive at net budgets of carbon and GHG exchange between wetland and adjoining estuary.
- *Science and Field Investigations*: The vertical gas fluxes will be calculated from the field data that have been collected thus far and statistical analyses will be applied to test differences between plant-defined marsh zones as well as changes with time.
- *Science and Field Investigations*: Net primary productivity will also begin to be quantified at Sage Lot Pond via above- and below-ground biomass collections.
- *GHG Methodology*: The final draft of the methodology will be completed, and the methodology will be submitted to a validator on the list approved by the Verified Carbon Standard. This will be accomplished through regular phone/Skype calls and email.
- *Biogeochemical Model:* The model will be further evolved using data generated from field season one.
- *Continued Engagement with Intended Users:* The team will develop and distribute progress reports and updates through various approaches to intended users and seek their feedback on initial findings, communications tools, and potential applications. These approaches include videos, fact sheets, brown bags, presentations, meetings, and website contact. The Collaboration Lead will work with the Science Investigators to organize a field trip for intended user representatives to allow them to become familiar with the type of data being collected, field sites, instrumentation being used etc and to have n opportunity to interact with the scientists as they are doing their fieldwork.
- *RFI – Transfer of Ideas:* The team will participate in three NERRS Science Collaborative funded projects to transfer project ideas to other NERRS sites.
- *Educational Workshop* – a workshop is being planned to educate conservation and restoration professionals and state and local decision-makers on the value of wetlands and highlighting carbon storage and GHG flux issues.

D. Benefit to NERRS and NOAA: List any project-related products, accomplishments, or discoveries that may be of interest to scientists or managers working on similar issues, your peers in the NERRS, or to NOAA. These may include, but are not limited to, workshops, trainings, or webinars; expert speakers; new publications; and new partnerships or key findings related to collaboration or applied science.

- *Boardwalk Design*: The boardwalk is composed of marine-grade fishing wire and pressure-treated wooden frames. The eight feet sections connect together and rest on plastic milk crates. This design provides >50% light penetration and keeps the foot traffic elevated, by

approximately one foot, off the marsh surface. So far, the boardwalk has proved a great success providing safe access to the vertical and lateral greenhouse gas measurement sites while protecting the salt marsh plant community. Jordan Mora created a slide show, and Meg Gardner created a video, on the boardwalk design and construction. The team believes this will be of great interest to NERRs, the National Park Service (NPS), and other salt marsh researchers – when the team was researching how to build a boardwalk which could be used to repeatedly access sampling sites without impacting the marsh, we discovered that there was not a standard, satisfactory method for doing this. As soon as some permitting details are completed, the team will make these tools available.

- *Videos*: Meg Gardner is creating a video series that will convey the major goals of the project, provide insight into the science being generated in the field, and show how end-users are incorporated into the project. The importance of conveying these messages is to allow the video audience to understand the project aims and why it may be beneficial to them. The video portraying the story behind building the boardwalk infrastructure can be used to help other reserves or marsh researchers seeking to find low-impact solutions in field work. Lastly, she will be creating two to three fact sheets in order to explain a few project concepts further, such as blue carbon and carbon markets.

- *Applied Science:* During summer 2012, a Woods Hole Oceanographic Institution Summer Student Fellow (undergraduate intern), Elizabeth Brannon (of Coastal Carolina University) participated in our field research. Her primary objective was to test the suitability of dissolved organic matter fluorescence measurements (colored dissolved organic matter, or CDOM) using a continuous sensor as a proxy for total dissolved organic carbon (DOC) concentrations. Her project was very successful, and results indicated that CDOM is a good proxy for DOC (Fig. 2).

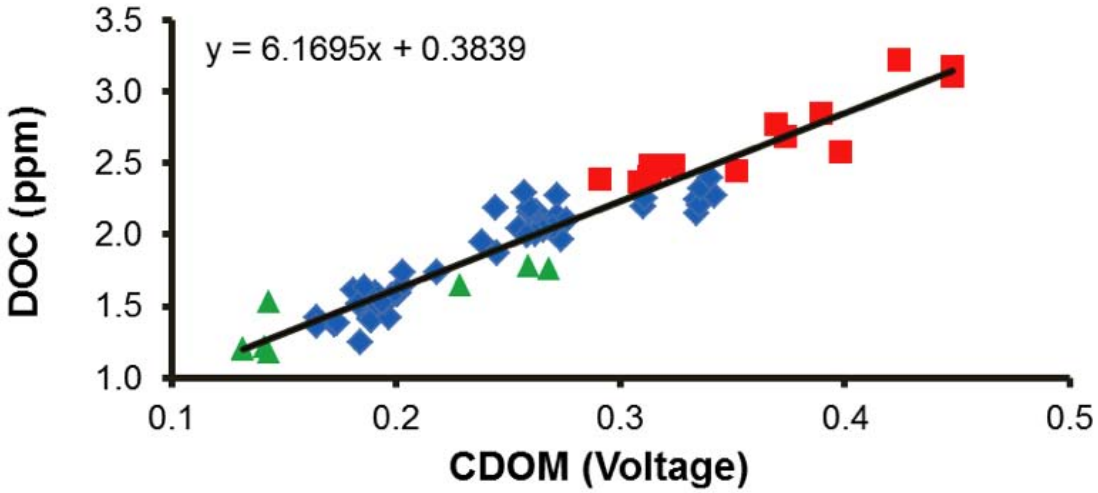

Figure 2. Measured dissolved organic carbon concentrations (DOC; measured by high temperature catalytic oxidation on an OI Analytical Aurora 1030 TOC Combustion Analyzer vs. field-measured CDOM fluorescence measured using a WetLabs fluorometer. Data are

from the Sage Lot Pond site, collected in April (green triangles), June (blue diamonds) and July (red squares) 2012.

E. Describe any activities, products, accomplishments, or obstacles not addressed in other sections of this report that you feel are important for the Science Collaborative to know.

Information on this research project has been incorporated in several educational programs at WBNERR such as the Teachers on the Estuary (TOTE) workshop, interpretative salt marsh ecology program for the public, and a summer science camp for teenagers. In addition, the Reserve's Stewardship Coordinator also led a field trip to the Sage Lot Pond site with members of the Mashpee Wampanoag tribal youth and scientists from the United States Geological Survey (USGS) and other research institutions. This was done as part of the Native Youth in Science – Preserving Our Homelands Project being coordinated by the USGS and Wampanoag tribal leaders.